A Review of Solar Desalination Application with Static Magnetic field and Phase Change Material

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***Abstract*: Because of the enormous use of clean water and its restricted availability relative to the amount of water on the Earth's surface, providing water fit for human consumption is one of the most pressing issues confronting the globe. The effect of adding a solar collector and phase change materials on distillation yield is examined in this study, and solar water desalination using solar distillation systems. Also, emphasize the system's influence of shedding a magnetic field and boosting evaporation by affecting water surface tension**

***Keywords:* Magnetic field, Phase Change Material, Solar Desalination.**

I. INTRODUCTION

Due to the recent energy crisis caused by the excessive use of fossil fuels, it is evident that there is a problem in obtaining clean water. Interest in renewable energy sources is increasing as they are alternative and environmentally safe sources. Due to the increasing need for water worldwide and the abundance of solar radiation, developing technologies harness solar energy to meet the human need for water [1]. The primary uses of solar energy discussed in this study are Solar water desalination. Given that traditional energy sources (oil, nuclear, coal, etc.) pose financial issues and harm human health and pollution, solar desalination is viable. Researchers have been urged to investigate the utilization of renewable energy sources (wind, solar energy, subsurface energy, and so on) since they do not affect the environment or human health. It is also notable for its rejuvenation. It's completely free. The essential renewable energy source is solar energy since it is plentiful and can be established in nearly every part of the world. Solar energy has various uses in everyday life, including electricity generation, water desalination, and water heating, among others [2-5].

1. Solar Distillation Unit (SDU).

Solar stills may be classified into two types: Active Solar radiation is the only heat source on which solar distillation systems depend. There are no additional components that use or create electricity. Added heat is supplied to the active distillation system by different geometries changes or complex designs. And there may also be the opportunity for additional parts that use or create power distribution beneficial to the system. Passive SDUs may be classified into two groups: traditional design and effective design. Traditional designs comprise simple stills with only reflective surfaces or condensers. Stepped basin, cylinder cover, concave, spherical, conical and triangular basin are all efficient designs and other types of still structures. These structures have a restricted yield output with passive operating characteristics and are only suited for a narrow population [6-7].

Many devices can be used to improve the performance of the solar distillation system. These devices (vacuum tubes, heat pipes, photovoltaic systems, and solar ponds, among others), Other types, such as flat plate collectors, boost mirrors, fans, and pumps, are used to grow the effectiveness of the solar still [6].

2. Solar Distillation Mechanism.

The solar water purification system works on the same principle as rain, where the water absorbs heat and evaporates and then condenses. Solar water distillation techniques provide a closed-loop, which is more efficient because of the complete management of the system so that it can be changed according to the required conditions. As shown in Figure 1, the solar still unit includes a glass cover, a water-resistant basin, and a black liner to increase the absorption of more solar energy. The basin is filled with salt or slightly saline water and left to be heated by the sun's heat. Then the steam rises and descends on the glass cover tilted at a certain angle and collects in a bowl. The remaining water containing salts and the suspended matter is left in the basin to be removed later [7].

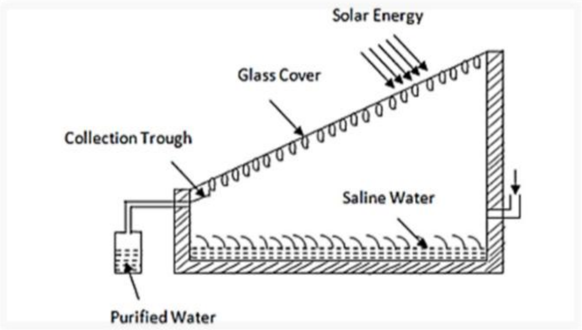


Figure (1) Working principle of the solar distillation unit [7].

Figure (2) illustrates the classification of the products of two types of solar distillation systems, namely the active and passive solar distillation system [8].

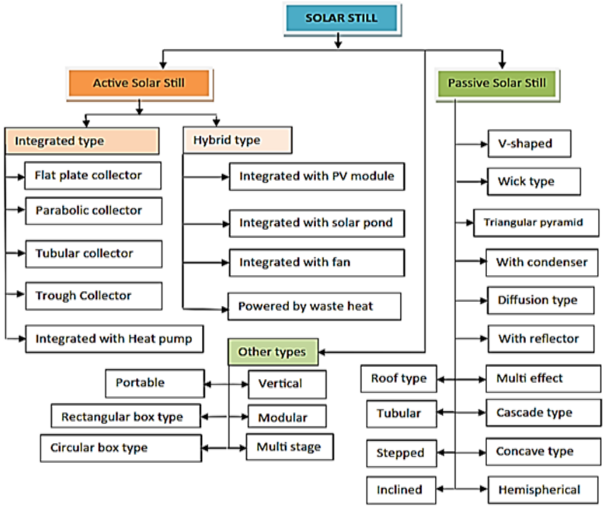


Figure (2) Classification of Solar Still [8].

II. PHASE CHANGE MATERIALS OF SOLAR STILL.

There are many heat storage systems in systems that collect heat from solar radiation. The best prominent of these systems is the thermal and chemical systems. Figure 3 illustrates the classification of heat storage's thermal and chemical systems in more detail [10].

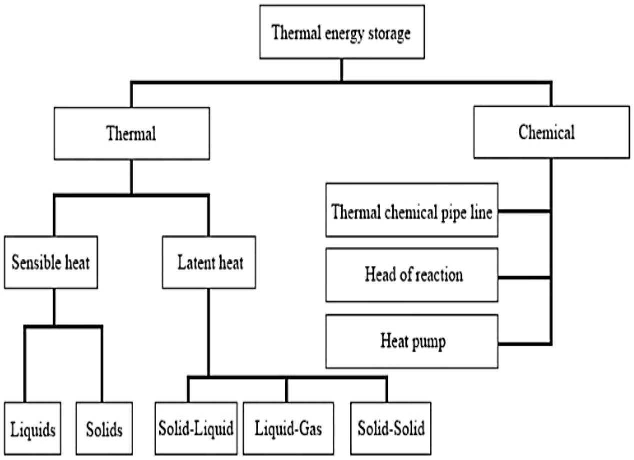


Figure (3) solar energy storage systems [10].

When calculating the cost, it is preferable to use thermal storage systems. The stored energy is latent or tangible by changing the temperature of the substance. Many researchers used different materials, such as basalt stones and steel wool fibers, to store heat. PCM materials undergo a phase change, absorbing and releasing heat and keeping heat about 14 times that of other materials, making them suitable for solar thermal storage systems. Phase change materials can be used at a lower melting temperature to get a lower operating temperature. In contrast, Phase-change materials have a high melting temperature and longer heat time [11].

3.1 Classification of PCM

There are two-phase change materials: organic materials include hydrocarbons, paraffin and wax, while inorganic materials contain molten salts and minerals. Organic compounds have a melting point of around 60°C, making them suitable for applications with temperatures as low as around 100°C. Inorganic compounds have a high melting point and a temperature between (130 to 1250) degrees Celsius, suitable for high-temperature applications.

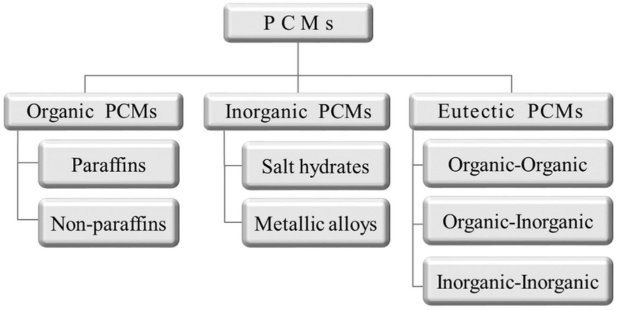


Figure (4) the classification of phase-change materials [11].

3.2 Properties of PCM.

The following Thermo physical, chemical, kinetic, and economic characteristics should be present in ideal phase change materials. [12]:

- Thermal characteristics: a melting point temperature within the desired variety, a great latent heat, a high degree of specific heat, and in both the solid and liquid phases, there is a large thermal conductivity.
- Physical qualities include a little volume variation during phase transition, a low level of vapor pressure, excellent phase equilibrium, and a high density.
- No/minimal supercoiling, high nucleation rate, and adequate crystallization rate are all kinetic qualities.
- Chemical qualities include chemical stability that lasts and a reversible phase transition.
- Economic qualities: Easy to find, inexpensive, and recyclable.

The productivity of the distillation system is determined by the amount of heat stored in the phase change materials. The organic compounds have a poor thermal conductivity coefficient ranging from (0.1 to 0.7) W/m. K, it takes a longer period to melt and re-freeze, so increasing the thermal conductivity of phase-changing materials is very important, the aim of which is to improve the work of the system [13].

III. THE EFFECTS OF MAGNETIC FIELD ON WATER TREATMENT.

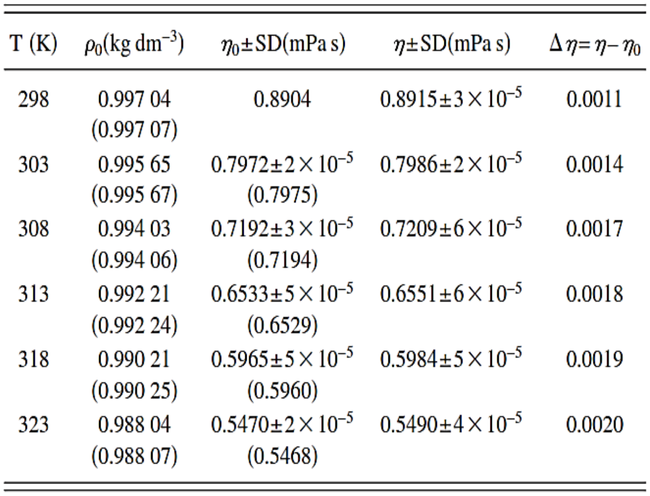
For more than 50 years' researchers have studied the effect of the magnetic field on water treatment. Previous studies focused on protecting industrial facilities from hard scale formation on home heating systems due to high temperatures [14].

3.1 The Influence of a Magnetic Field on Water Viscosity.

In the presence of an applied magnetic field, absolute viscosity is higher than in the absence of a field, which can be explained by stronger hydrogen bonding. At greater temperatures, the measurement constantly increases. Ghauri and Ansari [19] present these findings in their experiment, where the permanent magnet used had a field strength of 7.5 kg and the average flow time of water recorded at 25.0 ° C was 336.27s. Table 1 shows the viscosity of water under the influence of a magnetic field (1).

Table (1) Viscosities and densities of water at various temperatures, including standard deviations.

The subscript (0) denotes the absence of a magnetic field [19].

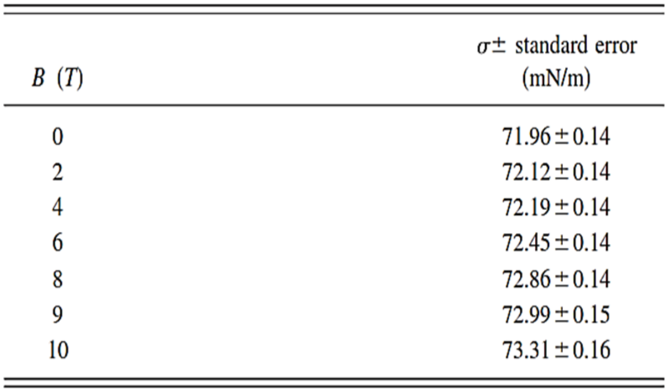


T (K)	ρ_0(kg dm^{-3})	η_0±SD(mPa s)	η±SD(mPa s)	$\Delta\eta=\eta-\eta_0$
298	0.997 04 (0.997 07)	0.8904	$0.8915\pm3\times10^{-5}$	0.0011
303	0.995 65 (0.995 67)	$0.7972\pm2\times10^{-5}$ (0.7975)	$0.7986\pm2\times10^{-5}$	0.0014
308	0.994 03 (0.994 06)	$0.7192\pm3\times10^{-5}$ (0.7194)	$0.7209\pm6\times10^{-5}$	0.0017
313	0.992 21 (0.992 24)	$0.6533\pm5\times10^{-5}$ (0.6529)	$0.6551\pm6\times10^{-5}$	0.0018
318	0.990 21 (0.990 25)	$0.5965\pm5\times10^{-5}$ (0.5960)	$0.5984\pm5\times10^{-5}$	0.0019
323	0.988 04 (0.988 07)	$0.5470\pm2\times10^{-5}$ (0.5468)	$0.5490\pm4\times10^{-5}$	0.0020

a. Water Surface Tension in High Magnetic Fields

Because of hydrogen bonding, water has high surface tension. Stabilization of hydrogen bonds and an increase in the number of hydrogen bonds at the surface would enhance the surface's internal energy, reduce surface entropy, and potentially result in a considerable net rise in Helmholtz available for free energy the interface. Gibbs free energy because of hydrogen bond stability, unlike Helmholtz free energy, does not rise with external action because of hydrogen bond expansion of size. As a result, the net increase in Gibbs free energy should equal the Gibbs free energy, quantified by a 4 cm difference in surface level at 10 to dubbed the Moses effect [20]. Surface tension rises with magnetic flux density, as seen in Table 2, increasing by 1.32 0.13 MN/m (1.83 in the absence of the magnetic field). The true surface tension divided by the density of water equals the relative changes in computed surface tensions.

Table (2) Data of the surface tension [20].



B (T)	$\sigma\pm$ standard error (mN/m)
0	71.96 ± 0.14
2	72.12 ± 0.14
4	72.19 ± 0.14
6	72.45 ± 0.14
8	72.86 ± 0.14
9	72.99 ± 0.15
10	73.31 ± 0.16

3. 2 Evaporation Rate and Magnetic Field

Evaporation is one of the physical properties of water that a magnetic device may affect. According to Yun-Zhu et al. [21], the evaporation rate rises considerably in the existence of a high magnetic field (over 8 T). This parameter is affected by the liquid/gas interface's surface, changes in hydrogen bond intensity, and Van der Waals forces. It appeared worthwhile to do more research on the effect of static MF on surface tension and water evaporation rate. We were particularly concerned about whether the trials carried out in real-world settings at a temperature in the room and many days with high humidity were repeatable and relevant. If that's the case, such findings might help accelerate water evaporation [16].

IV. LITERATURE REVIEW

Kabeel et al. [22] presented a theoretical analysis of a traditional solar still that stores thermal energy using phase transition materials, resulting in a 2–3 hour increase in operating system time and a 120–198 percent increase in solar still yield. This rise is influenced by several parameters, such as thermal conductivity and the PCM temperature melting temperature. The capricpalmitic material was chosen as a phase transition material because its employment increases solar distillation productivity.

*Szcze et al[**23**]*. At flow conditions, water was exposed to a weak static magnetic field (MF) created by a stack of magnets (B = 15 mT) or a single permanent magnet (B = 0.27 T) for various periods of time. Following the application of MF, the water conductivity and the amount of evaporated water were monitored as a function of time. And after the water has been distilled, the MF reduces the water conductivity, which is inversely proportional to the flow rate, and increases the amount of evaporated water. The effects are caused by the strengthening of hydrogen bond networks and the disturbance of the gas/liquid interface caused by air nano bubbles in the water.

*Agrawal [**24**]* The distilled of water with solar energy and (phase change material PCM) was investigated, as well as a comparison of solar stills with and without PCM. To compare solar still production throughout the day, two single-stepped solar still slopes were made, one with pcms and the other without. Paraffin wax was used as the phase transition medium. Solar distillation with PCMs increased production by 30% during the day and by 127% at night.This is because of a large mass of pcms in the basin reducing the mass of water in the basin, resulting in a clear improvement in the efficiency and output of daily distillate.

*Patil and Dambal [**25**]* employed a single basin with a double inclination as a solar still. The sensible heat was stored in black pebbles, and the phase transition material was paraffin. Experiments are conducted out in the open air, and the solar distillation basin, which measured 0.7 m2, was made of aluminium plates. The output of solar distillation while using paraffin was 1100 ml, the output when the distillery basin was painted black was 795 ml, and the output using black gravel was 954 ml, according to the data. Experiments revealed that mixing black gravel and paraffin resulted in the least solar distillation yield of 13%. The best productivity is 30 percent when using paraffin wax to coat the distillery basin, and 18 percent when using black gravel to coat the distillery basin.

Using phase change materials, *Faegh and Shafii [2**6**]* stored the latent heat energy of condensation water vapor within a solar still. The material paraffin wax is used for storing thermal energy. There is no direct contact between phase transformation materials and solar stills basin water in this study. Solar radiation is absorbed within the solar distillation process, which produces water vapor. It is then moved to an exterior capacitor holding the PCM in order to conserve and store the latent thermal energy generated during condensation for later use. To keep producing potable water, heating pipes are employed to transmit stored energy from the PCM to the solar distillation water. The findings show that using PCM in the exterior condenser while keeping the solar heating pipes attached to the solar evacuated tube collectors improved water output at night. When compared to when the PCM was not there, production increased by 86%. Water productivity is 6.555 L/m2 days, with an efficiency of 50%.

Arunkumar et al. [27] conducted an experimental and theoretical investigation of the efficiency of solar distillation coupled to a hemispherical solar concentrator with and without phase change materials. Using phase transition materials to store heat energy throughout the day and gain from them when the sun sets to ensure the generation of potable water continues. The results showed that using phase transition materials and solar concentrators resulted in a 26% increase in output, reaching 4460 ml/m2/day compared to 3520 ml/m2/day without PCM.

*Mousa et al. [2**8**]* built a theoretical model that models the solar collector's solar still. As Sodium Thiosulfate Pentahydrate, phase transition materials were chosen to store thermal energy. Which provides thermal energy and is employed as a suitable storage material in the continuous generation of drinking water during the night. When the PCM mass was increased from 10% to 100% of the basin water mass, the output dropped by up to 30%. The usage of PCM causes the water in the basin to remain at a high temperature for an extended period. When the flow rate is increased from 0.01 to 0.1 kg/s, the cooling effect of the glass cover boosts productivity by 37%. This item can supply hot water and drinking water.

V. CONCLUSION

1. Solar energy is among the most effective renewable energy sources since it can be found in some of the world's most environmentally favorable areas.
2. Phase change materials enhance the distillate's output since they store significant amounts of thermal energy to continue the water evaporation after nightfall.
3. The addition of a magnetic field to the distillation system improves the system's efficiency. It enhances the quantity of evaporation and the productivity of clean water by affecting the surface tension.

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